MODIS Semi-Annual Report
Snow and Ice Project
Reporting Period: July – December 1999
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Algorithm activities

We participated in the MOSS3 system test by ordering MODIS data products from the ECS NSIDC DAAC using the EDG. MODIS snow and sea ice data products were ordered from the NSIDC DAAC and quality assurance inspections were applied to data products received. Report of MOSS3 experience was submitted to the project.

Quality assurance (QA) procedures and investigations were applied to numerous MODIS snow and sea ice products produced during the MODAPS X-day, Y-day and J-day production test runs. The MEBDOS system was exercized and the LDOPE database and tools for evaluation of QA data were set for science quality flags in products. Fixes to the snow and sea ice algorithm codes and data products were made based on results of those QA procedures and investigations.

Versions 2.3.0 and 2.4.0 of the MODIS level 2 snow cover algorithm (MOD_PR10) and product (MOD10_L2) were developed, tested and delivered to the project. Incorporated in Version 2.4.0 were: enhanced handling of L1B input data, writing of coarse resolution latitude and longitude data, and generation of a coarse resolution snow cover product for support of global scale QA of the product.

Version 2.2.0 of the MODIS level 3 daily snow cover algorithm (MOD_PR10A1) and product (MOD10A1) was developed, tested and delivered to the project.

Version 2.1.5 of the MODIS level 3 eight-day snow cover algorithm (MOD_PR10A2) and product (MOD10A2) was developed, tested and delivered to the project.

Version 2.2.9 of the MODIS level 2 sea ice extent algorithm (MOD_PR29) and product (MOD29) were developed, tested and delivered to the project.

A patched version 2.1.1 of the MODIS level 3 daily sea ice extent algorithm (MOD_PR29A1) and product (MOD29A1) was delivered to the project.

Version 2.2.1 of the MODIS level 3 eight-day sea ice extent algorithm (MOD_PR29A2) and product (MOD29A2) was developed, tested and delivered to the project.

Further testing of the MODIS daily snow cover climate modeling grid (CMG) algorithm (MOD_PR10C1) version 2.0.0 was accomplished using daily snow products (MOD10A1) generated in the MODAPS.

Development, coding and testing of the MODIS daily sea ice climate modeling grid (CMG) algorithm (MOD_PR29C1) version 2.0.0 was initiated and progressed to advanced stage generating a prototype data product (MOD29C1).

Procedures and software tools for analysis and QA of snow and sea ice data products were improved and new ones developed as a result of investigating MODIS snow and sea ice products produced in MODAPS test runs and in testing of new versions of the product algorithm codes.

Development of a future MODIS/AMSR snow-cover and depth product

Data in the wavelength range 0.545 – 1.652 μm from MODIS will be used to map daily global snow cover at 500 m resolution. However, during darkness, or when the satellite's view of the surface is obscured by cloud, snow cover cannot be mapped using MODIS data. We show that during these conditions, it is possible to supplement the MODIS product by mapping the snow cover using passive microwave data from the SSM/I, albeit with much poorer resolution (25km versus 500m.) For a 7-day time period in March 1999, the prototype MODIS snow-cover product was compared with a prototype MODIS-SSM/I product for the same area in the mid-western United States (Tait *et al.*, submitted.) We used AVHRR data from the NOAA-15 satellite to simulate MODIS data, as the MODIS channels used for snow-cover mapping are similar to those on the AVHRR. The combined MODIS-SSM/I product mapped 9% more snow cover than the MODIS-only product where previously no surface information could be gleaned from the optical data due to the presence of clouds. Incorporating the SSM/I data resulted in a loss of resolution in some areas, however much of the high resolution snow-cover information was retained. Still, the improvement in snow cover mapping to include all weather conditions outweighs the reduction in resolution.

Web site

In preparation for receiving MODIS data in early February, we have been undertaking an extensive revision of our MODIS snow and ice Web pages.

Fractional snow mapping

There is a linear relationship between the percent of snow cover in a pixel, as seen from space, and the NDSI. In comparison with a sub-pixel snow-mapping technique (based on spectral-mixture modeling), developed by Rosenthal and Dozier (1996) and validated with aircraft and field measurements in the Sierra Nevada Mountains, California, the two techniques agree within about 10%, with higher agreement at the lower percentages of snow cover as seen in the table below. Fractional snow-cover measurements, validated by field measurements, are quite rare, so further validation must wait for the availability of simultaneously-acquired ETM+, aircraft and MODIS data to verify results.

NDSI derived percent snow	Mean absolute difference between NDSI and Spectral Unmixing	Standard Deviation
0-10%	1.60%	2.97%
10-20%	5.02%	0.08%
20-30%	8.89%	0.08%
30-40%	10.81%	0.08%
40-50%	12.19%	0.08%
50-60%	12.77%	0.08%
60-70%	13.05%	0.08%
70-80%	12.95%	0.08%
80-90%	11.01%	0.08%
90-100%	9.32%	0.10%
0-100%	9.74%	2.91%

February 2000 field experiment

Introduction

As part of our efforts to validate the Moderate Resolution Imaging Spectroradiometer (MODIS) snow and ice products, a field experiment and aircraft mission is planned beginning February 15, 2000. The mission will be conducted in Minnesota, North and South Dakota, Montana, as well as on the East Coast including sites overflown during the WINCE (winter ice and cloud experiment) in 1997 in Keene, NH and northern New York state. The NASA ER-2 aircraft, equipped with the MODIS Airborne Simulator (MAS) will be flown for 15 hours dedicated to this mission.

The MODIS snow validation mission, Snow and Ice Measurements for MODIS (SAIMM), will be conducted in conjunction with the Global Energy and Water Experiment (GEWEX) project field work which seeks to relate observed snow-water equivalent to spring snowmelt in three basins in the northern Great Plains (J. Foster/P.I.).

Objectives and Approach

The objectives of the Snow and Ice Measurements for MODIS (SAIMM) mission are to acquire simultaneous or near-simultaneous MODIS, MAS and air-photo and field measurements in order to validate the MODIS snow-cover products, and to compare MODIS and SSM/I (Scanning Multichannel Microwave/Imager) snow-cover maps. Snow and vegetation-cover measurements will be acquired in different land covers, and with various amounts of snow (including continuous snow cover and patchy snow cover) on the ground. We will validate the fractional snow cover.

Background

Several previous missions have been conducted to validate the MODIS snow-cover prototype algorithms in the pre-launch time frame. Notably, we were involved in the Alaska'95 mission in central Alaska in 1995 when we acquired MAS and field measurements, and the 1997 WINCE mission in the mid-western and north-eastern U.S. (Other missions prior to 1995 were also conducted.) Results from the AK'95 and WINCE'97 missions allowed us to calculate snow-mapping accuracy in various vegetation types using the MODIS snow-mapping prototype algorithms, and to further validate the algorithms. Analysis of snow-mapping results in several different land covers have allowed us to estimate hemispheric-scale snow-mapping errors.

Field measurements were also acquired in February 1998 in support of the GEWEX experiment.

Experiment Plan

Fifteen (15) ER-2 flight hours have been allotted to this project. Flight lines have been developed. These flight lines are designed to cover various land covers as well as to overfly the continental snowline if possible. Field parties will be measuring snow parameters along transects during the overflights.

Clear skies are desired for this mission, although scattered clouds should not present a problem. A range of illumination conditions is desired, however, generally the best illumination is desirable. A flight or partial flight with low-illumination conditions is also needed to test the algorithm under low-light-level conditions.

Two grid patterns will be flown. One will be flown over Theodore Roosevelt National Park in the western Dakotas, and the other will be flown over the Leech Lake region in northern Minnesota.

Field Measurements

The following people will be acquiring field measurements: Jon Barton, Al Chang, Jim Foster, Dorothy Hall, and Andrew Tait, all of GSFC Code 974, and Melody Tribbeck of the University of Reading, U.K. Klaus Bayr of Keene State College will acquire measurements of the Keene, NH sites.

Measurements include: snow depth and density, snow-surface grain size, a qualitative assessment of snow state (i.e., wet, dry, dirty) and snow coverage (e.g., 100%, 10%, etc.). Snow pits will be dug at regular intervals to fully characterize the snowpack and to collect snow-crystal samples for later analysis at the USDA in connection with the GEWEX experiment. Air temperature will be measured. Vegetation type and coverage will be measured and tree canopy density will be measured using spherical densiometers at all of the field sites.

Post-Mission Data Analysis

MODIS Level-3 snow-cover products of our study areas at 500-m spatial resolution will be compared quantitatively with MAS-derived snow maps at 50-m resolution and TM or ETM+-derived snow maps at 30-m resolution. We may also make use of the 15 m panchromatic band of the ETM+. In addition, we will utilize the National Hydrologic Remote Sensing Center (NOHRSC) 1-km resolution snow maps to compare with the MODIS 500-m and climate-modeling grid (CMG) maps.

In addition, the results of canopy density from the spherical densiometers will be compared with the MODIS (leaf-area index) LAI product.

Utilizing the CMG snow maps and the maps derived using SSM/I data, we will compare the amount of snow mapped. Discrepancies will be investigated. In this way, we will determine how closely the MODIS snow-cover maps determine the fractional snow cover in a pixel.

Development of the post-launch snow albedo product

A post-launch snow albedo algorithm was developed by Dr. Andrew Klein of Texas A&M University. The work is summarized in Klein and Hall, in press, as shown below. The full paper is available on request, and the abstract is shown below:

Snow albedo determination using the NASA MODIS instrument

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Abstract

In 1999, the Moderate Resolution Imaging Spectroradiometer (MODIS) is scheduled for launch aboard the first NASA Earth Observing System platform (EOS AM-1). This instrument will provide a global daily view of the Earth's seasonally snow-covered areas. Algorithms have already been developed to produce daily maps snow-cover extent with a spatial resolution of 500m from MODIS data acquired in the visible to shortwave-infrared regions of the electromagnetic spectra. Development efforts are now underway to use this spectral information to determine the albedo of these snow-covered surfaces.

Current MODIS algorithms determine albedo by constructing bidirectional reflectance distribution functions (BRDF) from multiple observations taken over a 16-day period by both MODIS and MISR, the Multi-Angle Imaging Spectroradiometer that also will be flown on EOS AM -1. However, for snow-covered surfaces more frequent albedo measurements are desired. Improved temporal sampling will be accomplished via a

simpler algorithm that assumes a BDRF to convert MODIS at-satellite radiances into surface albedo. Over forests the algorithm will utilize a simple isotropic scattering model. For surfaces with no or low-stature vegetation, such as cropland, tundra and ice sheets, the algorithm will account for the strongly forward scattering nature of snow reflectance. Topographic effects will also be considered. MODIS Airborne Simulator (MAS) images collected in February 1997 over the Midwestern United States during the Winter Cloud Experiment (WINCE) field campaign are being used to develop the prototype MODIS snow albedo algorithm.

Atmospheric corrections over snow remain a challenge and uncertainties in the effect of aerosols are expected to introduce an uncertainty in snow-albedo calculation of approximately 3%. Despite these limitations, a MODIS snow albedo product will represent a significant improvement over the current parameterization the snow albedo in Global Climate Models and Land-Atmosphere Transfer Schemes.

Snow video

Work is continuing on the snow video with Code 588. Monthly meetings are held and the project is progressing.

Presentations:

Hall, D.K., “Comparison of snow-cover maps from multiple data sets,” a poster presentation at the Eastern Snow Conference, June 2, 1999, Fredericton, N.B., Canada.

Hall, D.K., “Intercomparison of satellite-derived snow-cover maps,” a brief talk and poster presentation, International Glaciological Society Symposium, Zurich, Switzerland, 17 August 1999.

Publications:

Hall, D.K., S. Li, A. Nolin and J.C. Shi, 1999: Pre-launch validation activities for the MODIS snow and sea ice algoritms, Earth Observer, 11(4):31-35.

Hall, D.K., A.B. Tait, J.L. Foster, A.T.C. Chang and M. Allen, “Comparison of snow-cover maps from multiple data sets,” Proceedings of the 56th Annual Eastern Snow Conference, 2-4 June 1999, Fredericton, N.B., Canada, in press.

Hall, D.K., A.B. Tait, J.L. Foster, A.T.C. Chang and M. Allen, “Intercomparison of satellite-derived snow-cover maps,” Annals of Glaciology, in press.

Klein, A.G. and D.K. Hall, “Snow albedo determination using the NASA MODIS instrument, Proceedings of the 56th Annual Eastern Snow Conference, 2-4 June 1999, Fredericton, N.B., Canada, in press.

Tait, A.B; Barton, J.S and Hall, D.K., “A prototype MODIS-SSM/I snow mapping algorithm,” International Journal of Remote Sensing, submitted.